INVESTIGATING THE VIABILITY OF HYDROGEN PRODUCTION FROM SODIUM BOROHYDRIDE USING ORGANIC ACIDS AND EXTRACTS FROM SPOILT CITRUS FRUIT

A THESIS SUBMITTED TO THE DEPARTMENT OF CHEMICAL ENGINEERING TO THE SCHOOL OF POST GRADUATE STUDIES COVENANT UNIVERSITY, OTA, OGUN STATE, NIGERIA

BY

ENYOMEJI ADEMU IDAMA

M.ENG

MATRIC. NO: 15PCF01004

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF ENGINEERING IN CHEMICAL ENGINEERING

JUNE, 2018

ACCEPTANCE PAGE

This is to attest that this thesis is accepted as partial fulfillment for the requirement of the award of Master of Engineering (M.Eng) Degree in the Department of Chemical Engineering, Covenant University, Ota, Ogun State, Nigeria.

Mr. Ainwokhai, Philip J. _____

Secretary, School of Postgraduate Studies **Signature and Date**

Prof. Wara, Samuel. _____

Dean School of Postgraduate Studies **Signature and Date**

DECLARATION BY CANDIDATE

I hereby declare that this thesis submitted for the Degree of Master in Chemical Engineering at Covenant University is my own original work and has not previously been submitted to any other institution of higher learning. I further declare that all sources cited or quoted are indicated and acknowledged by means of a comprehensive list of references

IDAMA, ENYOMEJI ADEMU

CERTIFICATION

This is to certify that this research work titled "INVESTIGATING THE VIABILITY OF HYDROGEN PRODUCTION FROM SODIUM BOROHYDRIDE USING ACETIC ACID, CITRIC ACID AND EXTRACTS FROM SPOILT LEMON, LIME AND ORANGE" was carried out by Enyomeji Ademu Idama (15PCF01004) of the Department of Chemical Engineering, College of Engineering, Covenant University Ota, Ogun State, Nigeria.

_____ _____

Enyomeji A. Idama **Date**
Author

_____ _____

Prof. Vincent E. Efeovbokhan **Date**
Project Supervisor

_____ _____

Prof. Vincent E. Efeovbokhan **Date**
Head of Department

_____ _____

Prof. Josiah O. Bello **Date**
External Supervisor

DEDICATION

This project is dedicated to my first and most important teachers my parents Professor Ademu Idama and Barrister (Mrs.) Sarah Annette Idama and greatest of them all my Lord and Savior Jesus Christ. To my sisters Iye Ademu Idama (Attorney-at-law) and Mrs Ojonele Idama Sani whose moral and financial support has enabled this project become a reality and to the Fasting Festival Idama Family that has never ceased to strive together with me in prayers to God for me (Romans 15:30). The Lord reward you all immensely

LETTER OF TRANSMITTAL

Department of Chemical Engineering,
Covenant University, Ota,
Ogun State,
June, 2018.

The Head of Department,
Department of Chemical Engineering,
Covenant University, Ota,
Ogun State.

Dear Sir

LETTER OF TRANSMITTAL

In accordance with the regulations of Covenant University, I hereby submit a project report on "INVESTIGATING THE VIABILITY OF HYDROGEN PRODUCTION FROM SODIUM BOROHYDRIDE USING ACETIC ACID, CITRIC ACID AND EXTRACTS FROM SPOILT LEMON, LIME AND ORANGE" in partial fulfillment of the requirement for the award of Master in Engineering (M. ENG) Degree in Chemical Engineering at Covenant University.

Yours Faithfully

_____

ENYOMEJI ADEMU IDAMA
15PCF01004

ACKNOWLEDGEMENTS

I acknowledge with gratitude my colleagues Obot Isang Ime, Osanyintade Olugbenga O, Owolabi Tolulope Abisoye and Raji Obafemi Folorunsho whom I first met at Covenant University Ota, Ogun State, Nigeria for our team spirit and 'we can' attitude in all our endeavors together on campus. Much thanks goes to all the lecturers who had thought me in various courses Prof. James. A. Omoleye, Prof. Vincent. E. Efeovbokhan, Prof. A. N. Anozie, Prof. J. Odigure, Prof. Oyinkepreye D. Orodu, DR. Paul. A. L. Anawe, DR. J. D. Udonne, DR. J.S. Udohitinash, DR Augustine O. Ayeni, and Gabriel James Ameh (skills acquisition). Biochemistry department of Covenant University for the sample analysis using HPLC and finally to the supervisor of this project Prof. Vincent. E. Efeovbokhan who is also Head of Department Chemical Engineering.

ABSTRACT

With the fast depletion of fossil fuel sources for energy production and coupled with their negative impacts on the environment, the continued search for alternative sources that are renewable, sustainable and environmentally friendly has become imperative. This research examined the performance of sodium borohydride for the production of hydrogen gas using 5 ml each of organic acid (acetic acid) and extracts of spoilt citrus fruits (lime, lemon and orange) without the use of neither catalyst nor heat source. A three neck flat bottom flask was used in which sodium borohydride was reacted with extracts from the three spoilt fruits and acetic acid with concentrations of 1, 5, 7, 12 and 17.5 M. Volume of hydrogen gas produced were recorded and the results revealed that using 7 M solution of acetic acid and 1.0 gram sodium borohydride generated the highest volume of 2460 ml of hydrogen gas in 63.72 min while the undiluted extracts of spoilt orange, lemon and lime gave 100 ml in 0.68 min, 90 ml in 1.67 min and 60 ml in 0.5 min respectively. For the diluted fruit extracts, lime, orange and lemon at a dilution factor of 2 each, generated hydrogen gas of 80 ml in 0.5 min, 70 ml in 1.3 min and 70 ml in 0.62 min respectively. All the reactions took place at an ambient temperature of 27^{o}C. On further investigation of the spoilt citrus fruit extract using a high performance liquid chromatography (HPLC) it revealed the citric acid content of orange and lime was 1.31% and 0.17% respectively while the citric acid content was negligible in the extract of the spoilt lemon. Being able to conveniently retrieve hydrogen from its combined state when needed would advance the use of hydrogen as a source of energy.

TABLE OF CONTENT **PAGE**

TITLE PAGE I

CERTIFICATION II

DEDICATION III

LETTER OF TRANSMITTAL IV

ACKNOWLEDGEMENT V

ABSTRACT VI

TABLE OF CONTENTS VII

LIST OF TABLES IX

LIST OF FIGURES X

CHAPTER ONE: Introduction…..……..…....1

1.0 Introduction …….....1

1.1 Background of the Study …….....…….……1

1.2 Statement of the Problem .....…….....3

1.3 Aim and Objective of the Study .....…….…4

1.3.1 Aim of the Study ……..…4

1.3.2 Objectives of the Study ……..……4

1.4 Justification of the Study …….....4

1.5 Scope of the Study 5

CHAPTER TWO: Literature Review ……...…..……6

2.0 Literature Review 6

2.1 Renewable and Sustainable Sources of Energy 6

2.2 Emissions from Combustion of Fuels 6

2.3 Hydrogen as a Source of Energy 7

2.4 Storage of Hydrogen 8

2.5 Production of Hydrogen from Metal Hydrides 9

CHAPTER THREE: Materials, Equipment, Apparatus and Method 11

3.0 Materials and Method 11

3.1 Materials 11

3.2 Equipment / Apparatus 11

3.3 Procedure 11
3.3.1 Experimental set-up ……...11
3.3.2 Preparation of acetic acid concentrations 11
3.3.3 Design of Experiment 12
3.3.3.1 Reaction of Acetic acid with Sodium Borohydride 12
3.3.3.2 Reaction of Citric acid with Sodium Borohydride 13
3.3.3.3 Obtaining Extracts from Spoilt Citrus Fruits 14
3.3.3.4 Procedure for the Production of Hydrogen from Sodium Borohydride using Spoilt Citrus Extract ……..14

CHAPTER FOUR: Results and Discussions of Results 15
4.0 Results and Discussion of Results 15
4.1 Results 15
4.2 Discussions of Results 23
4.2.1 Dilution factors …….....23
4.2.2 Acetic acid solution (Tables 4.1 to 4.7)…….....23
4.2.3 Temperature 24
4.2.4 Confirmatory Test ……..…24
4.2.5 The effect of acetic acid concentration on the volume of hydrogen generated …….25
4.2.6 The effect of continuous dilution of sodium borohydride and citric acid mixture on the volume of hydrogen gas produced ……..26
4.2.7 The effect of extracts of spoilt citrus fruits on hydrogen gas generation from sodium borohydride ……..27

CHAPTER FIVE: Conclusion, Recommendation(s) and Contribution to Knowledge 29
5.0 Conclusion and Recommendation 29
5.1 Conclusion 29
5.2 Recommendation(s) 30
5.3 Contribution to Knowledge ……..…31

REFERENCES 32
APPENDIX A 37
APPENDIX B 40
APPENDIX C 44
APPENDIX D ……...48

LIST OF TABLES **PAGE**

Table 3.1: Volume(s) of stock acetic acid and water of dilution used ……..…12

Table 3.2: Scaled-down amounts of sodium borohydride and acetic acid reactants used….12

Table 3.3: Scaled-down amounts of sodium borohydride, citric acid and water ……...14

Table 4.1: Control experiment for hydrogen production from reaction of distilled water with sodium borohydride at an ambient temperature of 27℃ …….15

Table 4.2: Variation of hydrogen gas generation from the reaction of 1M of 5ml acetic acid with sodium borohydride at an ambient temperature of 27℃ ……..15

Table 4.3: Variation of hydrogen gas generation from the reaction of 5M of 5ml acetic acid with sodium borohydride at an ambient temperature of 27℃ ……...16

Table 4.4: Variation of hydrogen gas generation from the reaction of 7M of 5ml acetic acid with sodium borohydride at an ambient temperature of 27℃ …….17

Table 4.5: Variation of hydrogen gas generation from the reaction of 12M of 5ml acetic acid with sodium borohydride at an ambient temperature of 27℃ ……..18

Table 4.6: Variation of hydrogen gas generation from the reaction of 17.5M of 5ml acetic acid with sodium borohydride at an ambient temperature of 27℃ ……19

Table 4.7: Variation of hydrogen gas generation from the reaction of citric acid and sodium borohydride at an ambient temperature of 27℃ ……..19

Table 4.8: Results for reaction between sodium borohydride and extracted liquid of spoilt lime at an ambient temperature of 27℃ …….20

Table 4.9: Results for reaction between sodium borohydride and extracted liquid of spoilt lemon at an ambient temperature of 27℃ ……...21

Table 4.10: Results for reaction between sodium borohydride and extracted liquid of spoilt oranges at an ambient temperature of 27℃ ……..22

Table 4.11: HPLC Chromatogram Analysis of Spoilt Citrus Extract ……...28

Table C1: The effect of continuous dilution of sodium borohydride and citric acid mixture on the volume of hydrogen gas produced at an ambient temperature of 27℃ . .46

LIST OF FIGURES **PAGE**

Figure 4.1: Variation of hydrogen gas produced with the concentration of acetic acid ……25

Figure 4.2: Variation of hydrogen gas produced with continuous dilution of sodium borohydride and citric acid mixture...…….26

Figure 4.3: Volume of hydrogen gas produced against time for spoilt lime extract ……..27

Plate A1: Complete reaction set-up ……...…….37

Plate A2: Reactor ……..…….37

Plate A3: Storage and measurement of produced hydrogen gas ……..…….38

Plate A4: Point for combustion of hydrogen gas ……..…….38

Plate A5: Magnetic stirrer ……..…….……..…… 39

Plate A6: Condenser filled with silica gel ……..……39

Plate B1: Acetic acid glacial ……..……40

Plate B2: Sodium borohydride ……..……40

Plate B3: Silica gel ……..……..……..41

Plate B4: Citric acid…….41

Plate B5: Extracted liquid of spoilt oranges……...…….42

Plate B6: Extracted liquid of spoilt lemon……..……42

Plate B7: Extracted liquid of spoilt lime ……..……..43